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THE COVID-19 SHOCK AND A FISCAL-MONETARY POLICY MIX IN A MONETARY UNION

by Anna Bartocci*, Alessandro Notarpietro* and Massimiliano Pisani*

Abstract

This paper evaluates the macroeconomic effects of a monetary and fiscal policy mix implemented in a two-region monetary union in response to the COVID-19 shock. The pandemic is modelled as a mix of recessionary demand and supply shocks affecting both regions simultaneously and symmetrically, under two assumptions: the effective lower bound (ELB) constrains the monetary policy rate; and a fraction of households, labelled 'hand-to-mouth' (HTM), consume all their available income in every period. The main results are the following: first, higher lump-sum targeted fiscal transfers to HTM households and public consumption spending in one region, financed by issuing public debt, reduce the recessionary effects both domestically and abroad (via the trade channel). Second, the monetary union-wide recession is mitigated more effectively if both regions implement a fiscal expansion and the central bank limits the increase in long-term rates by purchasing sovereign bonds. Third, fiscal measures are less effective if sovereign bond yields increase relatively more in one region because investors perceive its bonds as risky. Effectiveness can be regained if a supranational fiscal authority issues a safe bond.

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A strong, symmetric fiscal response that offsets the economic damage from the pandemic is in the economic interest of all countries in the euro-zone.[1]

1 Introduction[2]

The recessionary macroeconomic effects on the euro area (EA) economy of the Covid-19 shock are of particular interest from both a theoretical and a policy perspective. First, the shock affects most severely low-income households, as they typically have very imperfect or no access at all to financial markets and therefore cannot smooth consumption in response to an unexpected fall in income. The drop in their income originates a large reduction in their consumption demand, since these households typically exhibit a high marginal propensity to consume.[3] Second, all countries in the EA are resorting to expansionary fiscal policy measures to support aggregate demand, possibly with different intensities reflecting the availability of fiscal space at the time of the shock. While fiscal policy is conducted mainly at country level, cross-country spillovers associated with intra-EA trade integration may call for a coordinated fiscal response. Third, while the central bank stabilizes union-wide inflation, the effective lower bound (ELB) constrains the use of the monetary policy rate and requires the central bank to deploy non-standard monetary policy measures.[4] Thus, the analysis of cross-country

[1] In: *Why we all need a joint European fiscal response.* Contribution by Fabio Panetta, Member of the Executive Board, European Central Bank, published by Politico on 21 April 2020.

[2] The views expressed in this paper are those of the authors alone and should not be attributed to the Bank of Italy or the Eurosystem. We thank Fabio Busetti, Paolo Del Giovane, Stefano Neri and two anonymous referees for useful comments. Any remaining errors are the sole responsibility of the authors.

[3] See Coenen et al. (2008).

[4] See Cova et al. (2017) and Neri and Gerali (2017) for an analysis of the low level of the natural interest rate in industrialized countries and its relation with the so called "secular stagnation".

spillovers, cross-country fiscal coordination, and macroeconomic interaction between monetary and fiscal policy is of paramount importance for an assessment of the policy response to the Covid-19 shock in a monetary union.

This paper evaluates the effectiveness of a monetary and fiscal policy mix in response to the Covid-19 shock by simulating a dynamic general equilibrium model of a monetary union calibrated to the EA. We use a New Keynesian, two-region monetary union model. For simplicity, we calibrate the two EA regions in a symmetric way. In particular, they have equal size and degree of openness. The remaining parameters of the model are calibrated in line with literature.

The main features of the model are the following ones.

First, in each of the two regions, labelled Home and rest of the EA (REA), there are three types of households, called "Ricardian," "hand-to-mouth (HTM)," and "restricted." Ricardian households have access to domestic and international financial markets and own domestic producers of physical capital. HTM households consume their available wage income in every period. Thus, their consumption is heavily affected by the drop in current income following the pandemic shock. Restricted households have access only to the market for domestic long-term sovereign bonds (thus, their access to financial markets is "restricted"). Moreover, they own, jointly with domestic Ricardian households, the domestic producers of physical capital. The financial market segmentation generated by the presence of restricted households allows non-standard monetary policy measures such as central bank asset purchases to have real effects.[5]

Second, in each region, the domestic fiscal authority (the government) can make resources available to HTM households through an increase in tar-

[5]See Chen et al. (2012).

geted lump-sum transfers, financed by issuing (short- and long-term) public debt. The latter is stabilized around its long-run target by adjusting lump-sum taxes paid by Ricardian households.

Third, the central bank of the monetary union sets the monetary policy rate according to a standard Taylor rule subject to the ELB. Once the ELB is reached, the central bank can implement non-standard measures to achieve its price stability objective, buying Home and REA long-term sovereign bonds in the secondary markets.

Fourth, in some simulations it is assumed that, following the debt-financed fiscal expansion, the sovereign spread exogenously increases in one region and induces a further rise in the long-term rate beyond the (mechanical) rise due to the increase in public debt. The exogenous rise in the sovereign spread captures in a stylized way concerns of investors about the regional fiscal space and public debt sustainability. Moreover, it assumed that the higher sovereign spread is fully passed-through to the interest rate paid by households and firms.[6] Alternatively, it is assumed that the fiscal expansion is financed by a sovereign bond issued by a monetary-union wide supranational fiscal authority and perceived by investors as a "safe" asset, i.e., different from the regional sovereign bond, it does not pay a spread over the risk-free rate.

We model the Covid-19 shock as a mix of cross-country symmetric demand and supply shocks. While the pandemic initially manifested itself as a supply contraction, the subsequent lockdown measures and the entailed large increase in uncertainty resemble a contractionary demand shock.[7] The shocks induce a recession in the EA and, thus, reduce the available income of

[6] See Corsetti et al. (2014) on the so-called "sovereign risk channel" of fiscal policy.
[7] Later in this section we discuss this point in detail.

HTM households and drives the policy rate to the ELB, under the assumption of no-fiscal policy response. We then study the fiscal policy response by alternatively assuming that (i) only the Home fiscal authority increases targeted, lump-sum fiscal transfers to domestic HTM households and public consumption; (ii) both Home and REA fiscal authorities simultaneously increase transfers to their HTM households and public consumption; (iii) the central bank, to favour the achievement of the inflation target, implements long-term sovereign bond purchases in the case of simultaneous fiscal response by both countries; (iv) the increase in transfers to HTM households and public consumption in each region is financed by a safe bond issued by a supranational fiscal authority.

The main results are the following. First, higher lump-sum targeted fiscal transfers to HTM households and public consumption spending in one region (Home), financed by issuing public debt, reduce the recessionary effects both domestically and abroad (via trade channel). The implicit fiscal multiplier of Home GDP is 0.9, that of REA GDP is 0.2.[8] Second, the monetary union-wide recession is more effectively mitigated if both regions implement expansionary fiscal measures and the central bank limits the increase in long-term rates by purchasing sovereign bonds. The implicit multipliers of both Home and REA GDP are 1.1 and rise to 1.4 in the case of central bank intervention. Moreover, following the central bank intervention, Home and REA inflation rates would be 0.7 percentage points higher than in the case of only fiscal stimulus. Third, cross-country simultaneous fiscal expansions are less effective if sovereign bond yields increase relatively more in one region (Home) because investors perceive the bond as risky (Home GDP multiplier

[8]The implicit multiplier is computed as the difference, in the fourth quarter, between GDP with fiscal stimulus and GDP without fiscal stimulus, divided by the size of fiscal stimulus. In the fourth quarter the fiscal stimulus ends and, in the no-stimulus scenario, GDP achieves its trough.

decreases to 0.8, REA multiplier to 1.0). Effectiveness can be regained if a supranational fiscal authority issues a safe bond.[9]

Our choice of modelling the pandemic as a mix of aggregate demand and aggregate supply shocks is grounded in the most recent literature on the macroeconomic effects of the Covid-19 shock. A growing number of contributions analyze the macroeconomic impact of the Covid-19 shock and the related policy options to counteract it, offering different views on the interpretation (and modelling) of the pandemic. Faria-e-Castro (2020) models the pandemic shock as a negative demand shock. According to Guerrieri et al. (2020), in the presence of nominal rigidities, supply shocks can trigger changes in aggregate demand that are larger than the initial supply shocks. Eichenbaum et al. (2020) suggest that an epidemic can be thought of as giving rise to negative aggregate demand and aggregate supply shocks. The aggregate demand shock arises because susceptible people reduce their consumption to lower their probability of being infected. The negative aggregate supply shock arises because susceptible people reduce their hours worked to lower their probability of becoming infected. However, the qualitative and quantitative responses of consumption, hours worked and investment depend very much on which shock dominates. Baqaee and Farhi (2020) use a parsimonious quantitative input-output model of the US economy to disentangle the contribution of demand and supply shocks and conclude that both are necessary to match the data, which features large reductions in real GDP but only mild deflation. More recently, IMF (2020) suggests that lockdowns and voluntary social distancing played a near comparable role in

[9] Asymmetric sizes and openness would modify the cross-country spillovers. The bigger and more open a region, the larger its spillovers to the other region. The cross-country asymmetry would not greatly alter the response of the EA variables to the cross-country symmetric pandemic shock and to the same fiscal measures simultaneously implemented in both regions.

driving the economic recession. On the empirical side, Brinca et al. (2020) estimate a Bayesian VAR on US data to try to separate labor demand and labor supply shocks. Their estimates suggest that two-thirds of the drop in the aggregate growth rate of hours in March and April 2020 are attributable to labor supply. Balleer et al. (2020) study price-setting behavior in German firm-level survey data during the Covid-19 pandemic and conclude that supply and demand forces coexist, but demand shortages dominate in the short run.

Based on the findings of these contributions, we model the pandemic as a mix of aggregate demand and supply shocks affecting each EA region symmetrically. Different from these contributions, we focus on the EA, the role of cross-country spillovers and the interaction between fiscal and monetary policy responses under the assumptions of ELB and imperfect access to financial markets.

Our paper contributes to the literature on the monetary and fiscal policy mix in a monetary union. Bianchi et al. (2020) simulate a DSGE model of the US economy to assess the implications of a coordinated fiscal and monetary strategy aiming at creating a controlled rise of inflation to wear away a targeted fraction of debt. The coordinated strategy enhances the efficacy of the fiscal stimulus planned in response to the Covid-19 pandemic and allows the Federal Reserve to correct a prolonged period of below-target inflation. Different from them, we focus our analysis on a monetary union and non-standard monetary policy measures. As in their case, we find that the policy mix has positive effects on inflation. Coenen et al. (2020) show that a combination of imperfectly credible forward guidance, asset purchases and fiscal stimulus is effective in undoing the distortionary effects due to the ELB, in particular when asset purchases enhance the credibility of the forward guid-

ance policy. Different from them, we focus on a mix of two particular fiscal measures, i.e., fiscal transfers to HTM households and public consumption. Bayer et al. (2020) distinguish between transfers conditional on being unemployed (that mitigate income risk and the adverse impact of the lockdown ex ante) and unconditional transfers (stabilizing income ex post only). They find that for unconditional transfers, the multiplier ranges between 0.1 and 0.5, for conditional transfers between 1 and 2. Different from them, we focus on ex post transfers and their interaction with non-standard monetary policy measures. Burlon et al. (2017) evaluate the impact of accommodative non-standard measures in correspondence of a debt-financed increase in public investment in a monetary union. Pietrunti (2020) analyzes the impact of monetary and fiscal policy coordination in a closed-economy New Keynesian model of the euro area. We focus on public transfers and public consumption spending and monetary-fiscal policy mix within a monetary union.

Benigno (2004) shows how monetary policy should be conducted in a general equilibrium two-region, currency-area model with monopolistic competition and price stickiness. This framework delivers a simple welfare criterion based on the utility of the consumers that shows the usual trade-off between stabilizing inflation and output. Gali and Monacelli (2008) report that in the presence of country-specific shocks and nominal rigidities, the policy mix that is optimal from the viewpoint of the union as a whole requires that inflation be stabilized at the union level by the common central bank, whereas fiscal policy plays a country-specific stabilization role, one beyond the efficient provision of public goods. Farhi and Werning (2017) find that the benefits of a fiscal union are larger, the more asymmetric the shocks affecting the members of the currency union, the more persistent

these shocks, and the less open the member economies. Different from these contributions, we provide a positive (i.e., not normative) analysis of monetary and fiscal policy interaction in a monetary union when the the ELB holds and access to financial markets is incomplete.

Our paper is also related to the literature on fiscal multipliers in large-scale DSGE models used in policy institutions. Among the others, Coenen et al. (2012) find that there is agreement across models on both the absolute and relative sizes of different types of fiscal multipliers and, in particular, fiscal policy is most effective if it has moderate persistence and if monetary policy is accommodative. Different from this contribution, we focus on the EA and the interaction among regional fiscal policies and the EA-wide monetary policy.

The paper is organized as follows. The next section describes model setup and calibration. Section 3 illustrates the simulated scenarios. Section 4 reports the results. Section 5 concludes.

2 Model

We provide an overview of the model (Section 2.1), describe the different types of households (Section 2.2), the capital good producers (Section 2.3), the monetary policy instrument rule (Section 2.5), the fiscal sector (Section 2.6), and briefly discuss the calibration (Section 2.7).

2.1 Overview

The model represents the EA economy composed of two regions: Home, and the rest of EA (REA). The size of the EA economy is normalized to 1. Home and REA have sizes equal to n, and n^*, respectively (with $n > 0$, $n^* > 0$,

and $n + n^* = 1$).[10]

Home and REA share the currency and the central bank. The latter sets the nominal interest rate, which reacts to EA-wide inflation and output according to a Taylor rule.

One crucial feature of the model is that the ELB is an endogenous constraint on the EA (short-term) monetary policy rate and that the central bank can purchase domestic long-term sovereign bonds in each EA region secondary market to try to stabilize inflation dynamics (in line with the medium-term inflation target).

Another key model feature is financial segmentation as in Chen et al. (2012), that allows central bank asset purchases to have real effects in our model.[11] In each EA region there are three types of households, labeled "restricted," "Ricardian," and "HTM." Restricted households have access only to the domestic long-term sovereign bond market and, joint with domestic Ricardian (see below), own shares of domestic "capital producers."

Ricardian households have multiple investment choices, because they invest in domestic short- and long-term sovereign bonds, and international short-term bonds, traded with Ricardian of the other country. Ricardian households own domestic firms operating in the final and intermediate sectors (other than the capital producers) and hold shares of the domestic capital producers. HTM households do not have access to financial markets and in each period consume all available labor income.

All households supply differentiated labor services to domestic non-financial firms (other than capital producers) and act as wage setters in monopolistically competitive labor markets, as they charge a wage markup over their

[10] For each region, size refers to the overall population and to the number of firms operating in each sector.

[11] See also Bartocci et al. (2017).

marginal rate of substitution between consumption and leisure. Wage and labor decisions are taken by Ricardian households for all households. The overall wage income is equally distributed across all households.

On the production side, there are (i) capital producers, (ii) firms that, under monopolistic competition, produce intermediate tradable goods, and (iii) firms that, under perfect competition, produce two final goods (consumption and investment goods).

Capital producers are firms that optimally choose investment in physical capital to maximize profits under perfect competition, subject to the law of capital accumulation and quadratic adjustment costs on investment, taking prices as given. They rent capital to domestic firms producing intermediate goods and rebate profits to domestic restricted and Ricardian households.

Intermediate tradable goods are produced combining domestic capital and labor. Given the assumption of differentiated intermediate goods, firms have market power. Thus, they are price-setter and restrict output to create excess profits. Intermediate tradable goods can be sold domestically and abroad. It is assumed that markets for tradable goods are segmented, so that firms can set a different price in each of the two regions.

The two final goods are sold domestically and are produced combining all available intermediate goods using a constant-elasticity-of-substitution (CES) production function. The two resulting bundles can have different composition.

In line with other dynamic general equilibrium models of the EA (see, among the others, Warne et al., 2008 and Gomes et al., 2010), we include adjustment costs on real and nominal variables, ensuring that consumption, investment, and prices react in a gradual way to a shock. On the real side, consumption habits and quadratic costs prolong the adjustment of

households consumption and investment, respectively. On the nominal side, quadratic costs make wages and prices sticky.[12]

In what follows, we report the equations describing main Home households' decisions (Section 2.2), Home capital goods producers (Section 2.3), Home intermediate sector (Section 2.4), Home fiscal policy (Section 2.5), and monetary union-wide monetary policy (Section 2.6). Similar equations hold for REA households and fiscal policy (we state it when this is not the case).

2.2 Households

In each EA region there are three types of households: Ricardian, restricted, and HTM households. Each of them have a specific mass over a continuum: $0 < \lambda_{ric}, \lambda_{res}, \lambda_{HTM} < 1$ for Ricardian, restricted, and HTM households, respectively. Their sizes are such that their sum is equal to 1, so that the total mass of households is equal to the dimension of the country.[13] We consider a symmetric equilibrium. Thus there is a representative household and representative firm for each type of household and firm, respectively.

2.2.1 Ricardian household

The representative Ricardian household maximizes her lifetime expected utility subject to the budget constraint. She invests in domestic short- and long-term sovereign bonds, riskless international short-term bonds, the latter are traded with Ricardian households of the other country. She holds domestic firms operating in the final and intermediate sectors (other than the capital producers), and own (constant) shares of the domestic capital

[12] See Rotemberg (1982).

[13] For instance, in the case of the Home country $n(\lambda_{ric} + \lambda_{res} + \lambda_{HTM}) = n$.

producer, together with restricted household and, thus, indirectly invests in domestic physical capital. The lifetime expected utility, in consumption C_{ric}, and labor L_{ric} is

$$E_t \left\{ \sum_{\tau=t}^{\infty} \beta_{ric}^{\tau} \left[\left(Z_{C,t} \frac{C_{ric,\tau} - bb C_{ric,\tau-1}}{1-\sigma} \right)^{1-\sigma} - \frac{L_{ric,\tau}^{1+\tau_L}}{1+\tau_L} \right] \right\}, \tag{1}$$

where E_t denotes the expectation conditional on information set at date t, $\beta_{ric} \in (0,1)$ is the discount factor, $bb \in (0,1)$ is the external habit parameter, $1/\sigma > 0$ is the elasticity of intertemporal substitution, $\tau_L > 0$ is the reciprocal of the Frisch elasticity of labor supply. The term $Z_{C,t}$ represents a consumption preference shock, that we use joint with other shocks to simulate the pandemic. The budget constraint is

$$\begin{aligned}
&B_{ric,t} + B_{ric,t}^{REA} + P_t^{long} B_{ric,t}^{long} \\
&= R_{t-1}^{B} B_{ric,t-1} + (1 - \Gamma_{B,t-1}) \left(R_{t-1}^{B,REA} B_{ric,t-1}^{REA} \right) \\
&+ \left(1 + \kappa^{long} P_t^{long} \right) B_{ric,t-1}^{long} + (1 - \tau_{w,t}) W_t L_t - \Gamma_{W,t} + \Pi_t^{prof} - (1 + \tau_{c,t}) P_{C,t} C_{ric,t} - TAX_t \\
&+ share_{k_{ric}} (1 - \tau_{k,t}) \left(R_t^K K_{t-1} - P_{I,t} I_t \right) \\
&- \frac{\phi_{ric,long}^{I}}{2} \left(P_t^{long} B_{ric,t}^{long} - share_{B_{ric}}^{long} \frac{\bar{P}^{long} \bar{B}^{long}}{n \lambda_{ric}} \right)^2 - \phi_{ric,long}^{II} P_t^{long} B_{ric,t}^{long},
\end{aligned} \tag{2}$$

where B_{ric}, B_{ric}^{REA}, and B_{ric}^{long} are the positions in domestic riskless one-period (short-term) nominal bonds, international riskless one-period (short-term) nominal bonds, and domestic long-term sovereign bonds, respectively. They are all denominated in euros. Bonds B_{ric} and B_{ric}^{REA} pay the (gross) the interest rates R^B and $R^{B,REA}$, respectively. The variable P^{long} is the price of domestic long-term domestic sovereign bonds. Following Woodford (2001), the bond is formalized as a perpetuity paying an exponentially decaying

coupon $\kappa^{long} \in (0, 1]$. The implied gross interest rate is

$$R_t^{long} = \frac{1}{P_t^{long}} + \kappa^{long}. \tag{3}$$

The variable Π^{prof} represents profits, rebated to households in a lump-sum way, from ownership of domestic firms other than capital producers. The term P_C is the price of the final non-durable consumption goods. The variable $TAX > 0$ is lump-sum tax paid to the government. Parameters τ_c, τ_w, and τ_k are tax rates paid on consumption, labor and capital, respectively $(0 \leq \tau_c, \tau_w, \tau_k \leq 1)$.

The parameter $share_{kric}$ is the share of capital goods producers held by the Ricardian households $(0 < share_{k_{ric}} < 1)$. It multiplies profits rebated by capital producers (K is the domestic physical capital stock, R^K its return, I investment in physical capital and P_I its price).

The term Γ_B is the adjustment cost on the internationally traded bond, the parameters $\phi^I_{ric,long}, \phi^{II}_{ric,long} > 0$ in the budget constraint represent the adjustment costs on long-term sovereign bonds.[14]

The parameter $0 < share^{long}_{B_{ric}} < 1$ is the share of overall supply of domestic long-term sovereign bonds, $\bar{B}^{long}$, held in steady state by the Ricardian household, and $\bar{P}^{long}$ the price of the bond in steady state. The variables W and L_{ric} are the nominal wages and the labor supplied by the generic Ricardian household, respectively. The household sets the nominal wage under monopolistic competition, taking as given the demand for labor by

[14] Adjustment costs on asset positions of households are needed to make the model stationary, given the assumption of incomplete financial markets. The term Γ_B is defined as

$$\Gamma_{B,t} \equiv \phi_{B1} \frac{exp(\phi_{B2}[B^{REA}_{ric,t} - \bar{B}^{REA}_{ric}]) - 1}{exp(\phi_{B2}[B^{REA}_{ric,t} - \bar{B}^{REA}_{ric}]) + 1}, \tag{4}$$

where ϕ_{B1}, $\phi_{B2} > 0$ are parameters. The term $\bar{B}^{REA}_{ric}$ is the steady-state position of the representative Home Ricardian household in the market. See Benigno (2009).

domestic firms in the intermediate sector and subject to quadratic wage adjustment costs. The term Γ_W in the budget constraint is the wage quadratic adjustment cost paid in terms of the total wage bill.[15]

The representative Ricardian household optimally chooses consumption, labor, short-and long-term bonds to maximize utility, subject to the budget constraint (Eq. 2) and to the demand for labor by firms in the intermediate sector. As the resulting first order conditions are standard, we do not report them to save on space.[16] Other households supply the same amount of working hours and get the same hourly wages as those of Ricardian households.

2.2.2 Restricted household

The representative restricted household with mass $0 \leq \lambda_{res} < 1$ in the Home population, maximizes a utility function similar to the one of the Ricardian households:[17]

$$E_t \left\{ \sum_{\tau=t}^{\infty} \beta_{res}^{\tau} \left[Z_{C,t} \left(\frac{C_{res,\tau} - bbC_{res,\tau-1}}{1-\sigma} \right)^{1-\sigma} - \frac{L_{res,\tau}^{1+\tau_L}}{1+\tau_L} \right] \right\}. \tag{6}$$

The restricted household invests in long-term sovereign bonds, holds constant shares of domestic capital goods producers and, thus, indirectly invests

[15] It is defined as

$$\Gamma_{W,t} \equiv \frac{\psi_W}{2} \left(\frac{W_t/W_{t-1}}{\Pi_{t-1}^{ind_W} \overline{\Pi}_{EA}^{1-ind_W}} - 1 \right)^2 W_t L_{ric,t}, \tag{5}$$

where the parameter $\psi_W > 0$ measures the degree of nominal wage rigidity, L_{ric} is the total amount of labor and $0 \leq ind_W \leq 1$ is a parameter that measures indexation to the previous-period (gross) price inflation and $1 - ind_W$ to the EA central bank (constant) gross inflation target.

[16] They are available upon request. Asset choices imply no-arbitrage conditions, that, up to first order, equate the expected returns on the different assets. The optimization problem for the choice of the optimal amount of work offered is solved only by savers.

[17] The term $Z_{C,t}$ is the same consumption preference shock that enters the utility function of Ricardian households.

in domestic physical capital. The budget constraint is

$$P_t^{long} B_{res,t}^{long} = P_t^{long} R_t^{long} B_{res,t-1}^{long} + (1-\tau_{w,t}) W_t L_{res,t}$$
$$+(1-share_{k_{ric}})(1-\tau_{k,t})\left(R_t^K K_{t-1} - P_{I,t} I_t\right) - (1+\tau_{c,t}) P_{C,t} C_{res,t}$$
$$-\frac{\phi_{res,long}}{2}\left(P_t^{long} B_{res,t}^{long} - share_{B_{res}}^{long} \frac{\bar{P}^{long}\bar{B}^{long}}{n\lambda^{res}}\right)^2, \tag{7}$$

where $(1 - share_{k_{ric}})$ is the share of capital goods producers held by the restricted households. The parameter $\phi_{res,long} > 0$ measures the adjustment cost on long-term sovereign bonds. The term $0 < share_{B_{res}}^{long} < 1$ is the share of (overall) long-term sovereign bonds held in steady state by the restricted household. She takes labor income as given, because both wage and hours worked are decided by the Ricardian household.

In the symmetric equilibrium the representative restricted household optimally chooses consumption and long-term sovereign bonds to maximize her utility subject to the budget constraint.

2.2.3 HTM household

Following Gali et al. (2004), it assumed that there is a representative HTM household, with mass $0 \leq \lambda_{HTM} < 1$. She is subject to the budget constraint

$$(1+\tau_{c,t}) P_{C,t} C_{HTM,t} = (1-\tau_{w,t}) W_t L_t + TR_t. \tag{8}$$

In every period the household consumes the overall available income and gets lump-sum transfers ($TR_t > 0$) from the domestic government. She takes labor income as given, because both wage and hours worked are decided by the Ricardian household. In the simulated scenarios lump-sum transfers sustain HTM consumption when labor income decreases.

2.3 Capital goods producers

There is a continuum of capital producers having the same size as that of the regional economy and acting under perfect competition. The representative capital goods producer is owned by domestic Ricardian and restricted households. Its stochastic discount factor is therefore a weighted sum of the Ricardian and restricted households' stochastic discount factors, with weights equal to the corresponding shares of capital producers' ownership.

The capital accumulation law is

$$K_t = (1-\delta) K_{t-1} + Z_{I,t} \left(1 - AC_t^I\right) I_t, \tag{9}$$

where $0 < \delta < 1$ is the depreciation rate. The adjustment cost on investment, AC^I, is

$$AC_t^I \equiv \frac{\phi_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2, \tag{10}$$

where $\phi_I > 0$ is a parameter. Investment I is a final non-tradable good, composed of intermediate tradable (domestic and imported) goods, its price is P_I.[18] Capital producers rent existing physical capital stock K_{t-1} in a perfectly competitive market at the nominal rate R_t^K to domestic firms producing intermediate goods. Profits are rebated in a lump-sum way to restricted and Ricardian households according to the corresponding shares $(1 - share_{k_{ric}})$ and $share_{k_{ric}}$, respectively.

The representative capital producer optimally chooses the end-of-period capital K_t and investment I_t subject to the law of capital accumulation, the adjustment costs on investment, and taking all prices as given.

The presence of restricted households and capital producers introduce

[18] Because of the adjustment costs on investment, a "Tobin's Q" holds.

financial segmentation in the model and, thus, allows non-standard monetary policy measures, like the sovereign bond purchases by central bank, to have real effects.

Finally, the term $Z_{I,t}$ in the capital accumulation law is an investment-specific shock, one of the exogenous shocks that we use to model the direct effects of the pandemic on the economy.

2.4 Intermediate sector

The intermediate goods are produced by firms under perfect competition, according to the production function

$$Y_t = K_{t-1}^{\gamma(1+Z_{\gamma,t})} L_t^{1-\gamma(1+Z_{\gamma,t})}, \tag{11}$$

where K_{t-1} and L_t are physical capital and labor respectively. The parameter γ, $(0 < \gamma < 1)$ is subject to a temporary positive shock, $Z_{\gamma,t}$ that represents a temporary change in technology conditions due to the government regulation in response to pandemic shocks. The interpretation is that firms are forced by the government to temporarily substitute capital for labor to adapt to the pandemic. For example, some workers are temporarily laid-off to respect imposed social distancing and those workers that continue to work have to receive additional equipment for safety reasons (safety devices, masks, glass or plastic screens, information technology equipment to work from home).

2.5 Monetary policy rule

We assume the following specification for the monetary-union wide monetary policy rule:

$$\frac{R_t}{\bar{R}} = max\left\{\frac{1}{\bar{R}}, \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_r}\left(\frac{\pi_{EA,t}}{\bar{\pi}_{EA}}\right)^{(1-\rho_r)\rho_\pi}\left(\frac{y_{EA,t}}{y_{EA,t-1}}\right)^{(1-\rho_r)\rho_y}\right\}. \quad (12)$$

The rule describes how the central bank conducts its monetary policy. The variable R_t is the gross policy rate and $\bar{R}$ its steady-state value. The parameters $0 \leq \rho_r \leq 1$, $\rho_\pi > 0$, ρ_y measure the sensitivity of the policy rate to its lagged value, to (quarterly) gross inflation rate (in deviation from the target $\bar{\pi}^{EA}$), and to the quarterly gross growth rate of output $y_{EA,t}/y_{EA,t-1}$, respectively. The monetary union-wide CPI inflation rate $\pi_{EA,t}$ is a geometric average of Home and REA CPI inflation rates (respectively π_t and π_t^*) with weights equal to the correspondent country steady-state GDP shares. The monetary union output, denoted $y_{EA,t}$, is the sum of Home and REA GDP.[19] The *max* means that we take into account the (endogenous) ELB (R is the nominal monetary policy rate in gross terms, thus it is equal to 1 at the ELB).

2.6 Fiscal sector

Fiscal policy is set in each bloc (Home and REA). The Home government budget constraint is

$$B_t - B_{t-1}R_{t-1}^B + P_t^{long}B_t^{long} - R_t^{long}P_t^{long}B_{t-1}^{long} = P_{H,t}G_t + TR_t - T_t - TAX_t \quad (13)$$

[19] The lagged interest rate ensures that the policy rate is adjusted smoothly and captures the idea that the central bank prefers to avoid large changes and reversals in its policy instrument.

The variable G_t represents government purchases of goods and services (i.e. public spending for consumption). Consistent with the empirical evidence, G_t is fully biased towards the domestic intermediate good. Therefore, it is multiplied by the corresponding price index $P_{H,t}$.[20]

$TR_t > 0$ are lump-sum transfers to HTM households, and $TAX_t > 0$ are lump-sum taxes imposed on Ricardian households.

The same tax rates apply to every domestic Ricardian, restricted, and HTM household. Tax rates on labor income, capital income, and consumption are $\tau_t^w, \tau_t^k, \tau_t^c$, respectively ($0 \leq \tau_t^w, \tau_t^k, \tau_t^c \leq 1$). Total government revenues from distortionary taxation T_t are given by the identity

$$T_t \equiv \tau_t^w W_t n L_t + \tau_t^k n R_t^k K_{t-1}((1 - share_{k_{ric}})\lambda_{res} + share_{k_{ric}}\lambda_{ric})$$
$$+\tau_t^c P_t n(\lambda_{ric} C_{ric,t} + \lambda_{res} C_{res,t} + \lambda_{HTM} C_{HTM,t}). \tag{14}$$

The government follows a fiscal rule defined on lump-sum taxes TAX_t to bring the public debt as a percentage of domestic GDP, $b_G^s > 0$, in line with its long-run (steady-state) target $\bar{b}_G^s$. The fiscal rule is

$$\frac{tax_t}{\bar{tax}} = \left(\frac{b_{G,t}^s}{\bar{b}_G^s}\right)^{\phi_G}, \tag{15}$$

where the parameter $\phi_G > 0$ calls for an increase (reduction) in lump-sum taxes as a ratio to GDP, tax, relative to its steady-state value $\bar{tax}$, whenever the current-period short-term public debt as a ratio to GDP, $b_{G,t}^s$, is above (below) the steady-state target, $\bar{b}_G^s$. Results somewhat depend on the fiscal instrument chosen to stabilize public debt and, in the case of taxation, on the extent to which it is distortionary. We choose lump-sum taxes to stabilize public finance as they are non-distortionary and, thus, allow a "clean" eval-

[20] See Corsetti and Müller (2006).

uation of the macroeconomic effects of public transfers to HTM households and public consumption. Moreover, when simulating the model, the fiscal rule in each country is not active during the fiscal stimulus, i.e., the regional fiscal authorities keep lump-sum taxes paid by Ricardian households constant as a ratio to GDP. The rules are active after the discretionary stimulus, consistent with fiscal authorities stabilizing public debt in the medium and long run (after the stimulus is over). For simplicity, it is assumed that the changes in issued long-term sovereign bonds are proportional to the changes in issued short-term sovereign bonds. Moreover, all distortionary tax rates (τ^w, τ^k, τ^c) are kept constant at their corresponding steady-state levels in all simulations.

2.7 Calibration

The model is calibrated at quarterly frequency. For simplicity, it is assumed that the two regions are symmetric. The chosen calibration allows our model to adequately capture the dynamics of the main EA variables and is in line with those of Warne et al. (2008) and Gomes et al. (2010), that develop large-scale DSGE models of the EA. The only key departure from these contributions is the chosen value of the natural rate. In line with the low estimates for the EA natural rate reported by Neri and Gerali (2017), we calibrate the model so that the net natural rate is equal to 0 in steady state. The steady-state net annualized inflation rate is 2%. In our model, the (nominal) gross policy rate is, in steady state, equal to the ratio between gross inflation and the households' discount factor.[21] We set the discount factor of Ricardian households to 0.9998, as reported in Table 2. Thus, the (net) policy rate is around 2% as well.

[21] The economy gross growth rate is always set to 1.

Table 1 reports the (flexible-price) steady-state equilibrium. Private consumption, public consumption, investment, and imports are set to 59%, 21%, 20%, and 20% of GDP, respectively.[22]

Table 2 reports parameters regulating preferences and technology. The elasticity of intertemporal substitution is set to 1 (i.e., log preferences in consumption) The discount factor of restricted households is 0.999. The consumption habit parameter is set to 0.7. The Frisch labor elasticity is set to 0.5. The share of Ricardian, restricted, and HTM households are set to 0.55, 0.2, 0.25. Ricardian households hold a share of capital producers equal to 0.4, restricted households equal to 0.6.

For the production of intermediate goods, we assume a Cobb-Douglas production function. The elasticity of output to physical capital is 0.35 and the elasticity to labor is 0.65. The depreciation rate of physical capital to 0.025.

For final goods, the elasticity of substitution between domestic and imported intermediate goods is 1.5. The weight of the domestic intermediate good is 0.8.

Table 3 reports the markups and the elasticities of substitution among intermediate tradables and among labor varieties. They are set to 6 and 4.3, respectively, which correspond to steady-state mark-ups of 1.2 and 1.3.

Table 4 reports the adjustment costs. The investment adjustment cost is equal to 6. Concerning nominal rigidities, the parameter measuring the cost for adjusting the price of goods is set to 380. The one for adjusting nominal wages is set to 400. The parameter that measures the degree of indexation

[22]In our model, overall public spending is equal to the sum of public consumption, public transfers and interest payment on public debt. According to national accounting, public consumption is equal to the sum of purchases and public wages. In the model we do not distinguish among the last two items.

to previous-period inflation is set to 0.7 for both prices and wages.

Table 5 reports the parameters of the monetary policy and fiscal rule. For monetary policy, the response to inflation, ρ_π, is relatively large and equal to 1.7, consistent with the estimated value reported by Warne et al. (2008). The policy rate is adjusted slowly, given that the corresponding coefficient, ρ_r, is set to 0.87. The response to output growth, ρ_y, is set to 0.1. For fiscal policy, lump-sum taxes respond to public debt according to a coefficient set to 0.6.

3 Simulated scenarios

The first scenario simulates that both Home and REA are subject to the same Covid-19 shock, modelled as a combination of recessionary consumption-preference, investment-specific, and technology shocks lasting four quarters. The consumption-preference shock directly affects Ricardian and restricted households. The shocks are cross-country symmetric. The scenario is run under the alternative assumptions that the ELB does not constrain or, in the second scenario, constrains the monetary policy rate. The shocks are calibrated to obtain a decrease in Home and REA GDP of around 10% (trough level) if the ELB endogenously binds. In the third scenario, in response to the recessionary shocks, the Home fiscal authority increases lump-sum transfers targeted to domestic HTM households and public spending for consumption for four quarters (in the fifth, the fiscal items are newly set to their corresponding steady-state values). The increases in transfers and consumption are financed by issuing public debt to domestic households. In the fourth scenario, both Home and REA fiscal authorities increase lump-sum transfers and public consumption for four quarters. The increases in trans-

fers and public consumption are financed by issuing new public debt. We simulate, in the fifth scenario, that the fiscal authorities and the EA-wide central bank both respond to the shock. The central bank in the initial period of the simulation announces and implements a long-term sovereign bond purchase programme in the secondary market to keep the long-term interest rates close to their baseline levels. In the final two scenarios it is respectively assumed that the yield on Home sovereign bonds exogenously increases more than in the REA region (sixth scenario) and that the monetary union-wide fiscal response is implemented by a hypothetical EA-common fiscal authority (seventh scenario). Finally, in the sensitivity analysis, we simulate the policy mix under the assumption of a higher share of HTM households in the population.

In all scenarios the fiscal package is set, in each region, to 4% of baseline (steady-state) GDP, a value in line with the size of fiscal packages implemented in some EA countries. The increases in transfers and public consumption are, for simplicity, assumed to be 2% of baseline GDP each. The regional fiscal authorities keep lump-sum taxes paid by Ricardian households constant as a ratio to GDP during the first four quarters (the fiscal rules described by Eq. 15 are not active in those quarters). All scenarios are run under perfect foresight. Thus, all shocks but the initial one (i.e., the surprise) are perfectly anticipated by households and firms and the fiscal and monetary policy responses are fully credible.

4 Results

4.1 Recessionary shock and the ELB

Fig. 1 reports the responses of the main macroeconomic variables to the Covid-19 shock under the alternative assumptions of ELB constraining or not constraining the policy rate. Consumption and investment widely decrease in both Home and REA. Given the lower aggregate demand, firms reduce production and labor demand. Lower hours worked and real wage force HTM households to reduce their consumption that in each period is equal to wage income.[23] The presence of HTM households, thus, amplifies the negative effects of the shock on aggregate consumption. Lower aggregate demand in one region has negative spillovers to the other one, via lower imports.[24]

Moreover, lower aggregate demand induces firms to decrease prices in both regions. As a result, EA inflation decreases relative to the baseline. The central bank reacts to lower inflation and economic activity in the EA by reducing the policy rate, according to the Taylor rule (see Eq. 12). In the ELB-scenario, the policy rate hits the ELB.[25] The constant nominal policy rate and the lower expected inflation positively affect the real interest rate. The latter increases and widely amplifies the recessionary and deflationary effects of the shock. Home and REA GDP decrease by 7.6% in absence of the ELB, 10.9% if the ELB binds. The endogenous ELB lasts about three

[23] Absent the ELB, real wages mildly increase in the initial periods, then start declining and fall below their steady-state after around six quarters. The initial response reflects the relatively higher stickiness of nominal wages compared to prices. When the ELB binds, real wages immediately fall, because the recessionary effects of the shock are amplified.

[24] The overall effects are symmetric, given the nature of the shock and the calibration of the two regions.

[25] We assume that there is little space for the central bank to reduce the policy rate, consistent with the very low level of the EA policy rate at the moment of the pandemic shock.

years.

In order to disentangle the role of the shocks, Fig. 2 reports the responses of the main macroeconomic variables if only the technological shock affects the economy (see Eq. 11). The effects are recessionary. Because of the Covid-19, firms substitute capital for labor. Hours worked and real wages decrease and increase, respectively. The increase in real wages is mild and reflects the relatively higher degree of stickiness in nominal wages, as opposed to nominal prices (nominal wages, not reported to save on space, decrease to a lower extent than nominal prices). HTM households reduce consumption. In equilibrium, firms reduce investment as well as prices, consistent with lower consumption demand. Inflation decreases as well. The monetary policy rate hits the ELB, amplifying the recessionary effects of the Covid-19-induced change in technology conditions.

4.2 Recessionary shock, ELB, lump-sum transfers to HTM households, and public consumption

The ELB-scenario is newly run assuming that the Home fiscal authority increases lump-sum transfers to domestic HTM households and public consumption for four quarters. Each spending item is increased by 2% of steady-state GDP. In the fifth quarter they are newly set to their corresponding steady-state values. The Home fiscal authority finances the increase in spending by borrowing from domestic Ricardian households. As a result, Home public debt temporarily increases as a ratio to GDP. Home taxes paid by Ricardian households are newly raised to stabilize public debt after four quarters. The REA fiscal authority, instead, keeps lump-sum transfers to domestic HTM households and public consumption at their baseline levels.

As shown in Fig. 3, higher public spending helps to offset the Home

recession. Relative to the no-public spending scenario, Home HTM households have higher available income and immediately increase consumption, since their marginal propensity to consume out of income is one. The improvement in aggregate consumption induces Home firms to decrease to a lower extent production and, thus, hours worked and investment in physical capital. Home GDP decreases less than in the no-Home public spending case.

The improvement in Home aggregate demand is matched not only by domestic production, but also by imports of goods and services produced by REA. Thus, the increase in Home public spending has positive spillovers to REA macroeconomic conditions. This is a consequence of the trade integration among the two regions (both Home and REA exports are set to 20% of the corresponding GDP). In the fourth quarter (last quarter of the stimulus implementation), Home GDP decreases by 7.4% and REA GDP by 10.1%, instead of 10.9% as in the case of no-stimulus. Thus, the implicit multipliers in the fourth quarter are 0.9 (Home GDP) and 0.2 (REA GDP), respectively (see Table 6).

Trade integration and the related expansionary spillovers could justify a simultaneous increase in both Home and REA transfers to domestic HTM households and public consumption implemented by the corresponding fiscal authorities. Fig. 3 reports this case, i.e., it is assumed that also the REA fiscal authority exogenously increases targeted lump-sum transfers to domestic HTM households and public spending for consumption for four quarters. Relative to the Home-public spending case, REA GDP decreases to a lower extent, because of the expansionary impulse associated with domestic public spending and higher HTM households' consumption. The Home economy also benefits from the REA fiscal impulse. Home exports to REA decrease to

lower extent, consistent with the lower decrease in REA aggregate demand. Home GDP and, thus, hours worked decrease less, inducing the Home fiscal authority to increase transfers and public debt to a lower extent. Home GDP decreases by less than in no-fiscal response and Home-fiscal response cases, respectively. In the fourth quarter, both Home and REA GDP decrease by 6.4%, instead of 10.9% (case of no fiscal stimulus). The implicit multipliers of Home and REA GDP are both equal to 1.1.

Overall, results suggest that a simultaneous cross-region fiscal response can somewhat offset the recessionary effects of the pandemic shock.

4.3 Long-term sovereign bond purchases by the central bank

We assess the interaction between fiscal and monetary policy at the ELB by assuming that both Home and REA fiscal authorities simultaneously increase fiscal transfers and public consumption spending and, at the same time, the central bank implements a long-term sovereign bond purchase programme to favour the achievement of the inflation target. The amount of purchases is calibrated to roughly keep the long-term rates unchanged at their baseline level. Purchases of Home and REA sovereign bonds are proportional to corresponding Home and REA (GDP) shares of EA GDP.[26]

Fig. 4 shows the responses of the main variables. Home and REA GDP decrease to a much smaller extent than under the no purchase programme-case. In the fourth quarter, Home and REA GDP decrease by 5.2% instead of 10.9% as in the no-fiscal stimulus case. The implicit fiscal multiplier is 1.4 (see Table 6). The reason is that Home and REA long-term interest rates mildly decrease, because the prices of the bonds, inversely related to

[26]See Burlon et al. (2017) for a similar analysis applied to the increase in public investment in a monetary union.

their yields, increase in correspondence of the higher demand by the central bank. Ricardian and restricted households sell their bonds to the central bank and, thus, substitute consumption and investment in physical capital, whose return is relatively high, for bonds. The additional monetary stimulus favors both Home and REA aggregate demand that increase relative to the case in which only the fiscal response to the Covid-19 shock is implemented. Trade intensity improves as well, in line with the higher aggregate demand. The expansionary fiscal and monetary policy mix, by providing a larger sustain to aggregate demand, also improves inflation dynamics. Inflation decreases to a lower extent in both regions. Following the central bank intervention, Home and REA inflation rates would be 0.7 percentage points higher than in the case of only fiscal stimulus. Thus, the central bank starts to raise the policy rate out of the ELB earlier than in the other considered scenarios. Monetary policy normalization, i.e., the return to a standard Taylor rule away from the ELB, is faster.

Overall, the results suggest that, at the ELB, the expansionary fiscal and monetary policy mix is the most effective way to offset the effects of a large, symmetric EA-wide recessionary shock like the Covid-19.

4.4 Increase in Home sovereign spread

In the previous simulations, the increase in public debt to finance increased targeted transfers and public consumption spending was not accompanied by financial tensions. The interest rate on short-term public debt was at its baseline level, because it is equal to the monetary policy rate. The interest rate on long-term sovereign bond raised, consistent with the changes in fundamentals, i.e., the higher demand of funds by the government.

Our model features an endogenous spread (term-premium) between short-

and long-term bonds, due to the adjustment cost on long-term bond positions paid by Ricardian households. However, the model does not explicitly feature sovereign risk. To introduce it, we now assume that the interest rate paid by the Home short-term government bond is equal to the sum of the monetary policy (risk-free) rate and an exogenous spread that we interpret as capturing changes in the sovereign risk premia (sovereign risk channel). The sovereign spread enters directly the consumption Euler equation of the Home Ricardian households and, via the no-arbitrage conditions implied by the first order conditions, it alters the yield on long-term bonds as well, thus indirectly affecting all consumption and investment decisions (i.e., there is a quick and complete pass-through of sovereign spread to households' and firms' borrowing and lending conditions).[27]

In principle, the spread increase may or may not be related to changes in the fundamentals of the Home economy. In order to motivate the increase in the sovereign spread, in this scenario we relax the symmetry assumption and instead impose that the Home region has a relatively higher public debt-to-GDP ratio. We set it to 125% in steady state, as opposed to 100% in REA. When the Home economy enacts an expansionary fiscal policy in response to the pandemic-related recessionary shock, its public debt is perceived as risky and the sovereign spread increases.

The exogenous increase in the Home sovereign spread is assumed to be temporary and of a rather limited amount, as our aim is not to describe the effects of a sovereign crisis but, instead, those of non-extreme financial tensions during the fiscal expansion. Thus, the assumed spread increase induces, via no-arbitrage conditions, an additional rise in the Home long-

[27] Corsetti et al. (2014) propose a New Keynesian model of a two-region monetary union that accounts for the sovereign risk channel. They show that a combination of sovereign risk in one region and strongly procyclical fiscal policy at the aggregate level exacerbates the risk of belief-driven deflationary downturns.

term interest rate equal to around 50 annualized basis points on average in the first year.[28] Moreover, to highlight the role of the sovereign risk channel, we assume that the central bank follows the Taylor rule and that it does not implement non-standard monetary policy measures (i.e., sovereign bond purchases).

Fig. 5 shows the responses of the main variables. Compared to the case of no-spread increase, the stimulus is less expansionary. Higher Home spreads induce Ricardian and restricted households to increase consumption and investment in physical capital to lower extent. As a consequence, the relative increase in labor demand is lower and so is the increase in HTM households' income. The latter households increase their consumption to a lower extent. Home GDP decreases more than in the case of fiscal stimulus without exogenous spread increases. Crucially, spillovers of the Home stimulus to the REA are less expansionary, because of lower Home imports of REA products (in the fourth quarter, Home GDP decreases by 7.9% and REA GDP decreases by 7.1%, instead of 6.4% as in the case of simultaneous fiscal stimulus and no-spread increase). The implicit Home and REA multipliers decrease to 0.8 and 1.0, respectively (they are both equal 1.1 in the case of simultaneous cross-regional stimulus and no-spread increase, see Table 6). Thus, GDP and inflation further decrease in both Home and REA relative to the no-exogenous spread increase scenario. The decreases in Home and REA GDP are closer to those registered in the scenario without (joint) fiscal stimulus.[29]

[28] Laubach (2010) studies the dependence of the sovereign spread on the current level of fiscal indicators (such as the surplus-to-GDP or the debt-to-GDP ratios) for a panel of EA countries and finds that the elasticity is small or nil in non-crisis periods but increases rapidly and dramatically at times of financial stress.

[29] The reduction in the fiscal multiplier would be larger with a larger and more persistent increase in the sovereign spread, as in the case of a sovereign crisis. See Gerali et al. (2018) for an evaluation of the sovereign-risk channel during the European sovereign crisis. See Locarno et al. (2013) for an analysis of the sovereign risk channel and fiscal multipliers.

Overall, regional financial tensions associated with local public debt issuance can limit the effectiveness of the simultaneous EA-wide fiscal stimulus.

4.5 Public debt issued by a supranational fiscal authority

One possible way to avoid financial tensions in one of the regions is to finance the very same fiscal stimulus with EA-wide short- and long-term bonds, issued by a hypothetical supranational fiscal authority, backed by future tax revenues in both regions.[30] Thus, as long as these bonds are perceived as "safe" by investors, they should plausibly not generate increases in spread associated with region-specific financial tensions. The bonds are sold to both Home and REA Ricardian households. The budget constraint of the EA-wide fiscal authority is

$$\begin{aligned} & B_{G,t}^{EA} - B_{G,t-1}^{EA} R_t + P_t^{EA,long} B_{G,t}^{EA,long} - P_t^{EA,long} R_t^{EA,long} B_{G,t-1}^{EA,long} \\ & \quad = TR_{H,t}^{EA} + TR_{REA,t}^{EA} + G_{H,t}^{EA} + G_{REA,t}^{EA} - TAX_{H,t}^{EA} + TAX_{REA,t}^{EA}, \end{aligned} \tag{16}$$

where B_G^{EA} is the short-term (one-period) bond, $B_G^{EA,long}$ is the long-term bond, $P^{EA,long}$ its price and $R^{EA,long}$ its long-term rate, G_H^{EA} and G_{REA}^{EA} are respectively public consumption spending in Home and REA, TR_H^{EA} and TR_{REA}^{EA} are respectively transfers to the Home and REA HTM households, TAX_H^{EA} and TAX_{REA}^{EA} are lump-sum taxes respectively paid by Home and REA Ricardian households to their government and rebated by the latter to the EA-supranational fiscal authority. Transfers and public consumption are assumed to be exogenous, while EA lump-sum taxes are endogenously

[30] We do not consider the case of central bank intervening in the secondary markets for monetary policy purposes in response to financial tensions. Instead, we focus on the design of the supranational fiscal policy.

set, as a ratio to EA GDP (tax^{EA}), to stabilize the short-term public debt, as a ratio to EA GDP (b_G^{EA}), according to the following rule:

$$\frac{tax_t^{EA}}{\overline{tax}^{EA}} = \left(\frac{b_{G,t}^{EA}}{\overline{b}_G^{EA}} \right)^{\phi_G^{EA}}, \tag{17}$$

where $\overline{tax}^{EA}$ and $\bar{b}_G^{EA}$ are the steady-state values of the taxes and short-term public debt (ratio to EA GDP), respectively. Long-term bond issuance is such that the change in the value of long-term bonds is the same as the change in the value of short-term bonds, both as a ratio to EA GDP. All fiscal items of the EA supranational authority are set to zero in steady state. The term $\phi_G^{EA} > 0$ is a parameter, set to 0.6. Taxes are paid by each country according to the corresponding (GDP) share of EA GDP. The rule is not active during the four-quarter EA-wide fiscal stimulus and is calibrated like the national fiscal rules (see Eq. 15). Moreover, it is assumed that national fiscal authorities do not raise transfers to HTM and public consumption, since the expansionary fiscal policy response to the common shock is now delegated to the EA-wide fiscal authority.

Fig. 6 shows the results. They are similar to those obtained if the transfers and public consumption are simultaneously raised by national fiscal authorities and the Home spread does not rise. The reason is that the amount and distribution of fiscal resources is the same in both cases and that Ricardian households have access to multiple financial markets to smooth the effects on consumption of the raise in taxation. Thus, the equilibrium is essentially the same. Macroeconomic conditions improve relative to the case of the stimulus financed by issuing national public debt when the Home spread increases.

All in all, a fiscal stimulus financed by issuing EA-wide bonds can be

rather effective as long as the bonds are perceived as safe, i.e., the supranational fiscal authority makes a credible commitment to pay back its debt by raising future taxes.

4.6 Sensitivity: higher share of HTM households

We assess the effectiveness of the mix of (i) non-standard monetary policy and (ii) cross-region simultaneous fiscal policy under the assumption that the share of HTM households in each region is 50% of the population, instead of 25%.

Fig. 7 reports the results. Home and REA GDP decrease to a slightly lower extent if the share of HTM households is higher. The higher share of HTM households implies that consumption of each HTM household increases by less, because the given amount of transfers is now distributed to a larger share of HTM households. However, aggregate demand decreases slightly less and so does economic activity. Inflation rate decreases to a lower extent and the ELB lasts less periods.

Overall, results suggest that the policy mix is effective in an environment, like the pandemic one, that is likely to be characterized by a high share of households featuring lack of access to financial markets.

5 Conclusions

We have analyzed the macroeconomic effects of country-specific and cross-country coordinated fiscal and monetary measures in a monetary union where the ELB constrains the monetary policy rate following a large recessionary shock like the one implied by the Covid-19 pandemic. The main results suggest that country-specific unilateral fiscal responses to union-wide

recessionary shocks mitigate not only the (recessionary) effects on the domestic economy but also those on the rest of the monetary union, because cross-country spillovers of recessionary and fiscal shocks are amplified by the ELB. The magnified size of spillovers, associated to trade-leakages in our model, calls for cross-country simultaneous fiscal responses. Moreover, monetary policy could provide a non-trivial contribution to offset the recession by adopting an accommodative stance (that is, by lowering long-term interest rates) in correspondence of the fiscal measures. Our results suggest that the relevance and the need of designing an appropriate fiscal and monetary policy mix in a monetary union are very important in the presence of the ELB, imperfect access to financial markets, and in the face of a large recessionary shock common to all Member States of the monetary union.

This paper can be extended along several dimensions. Liquidity and financial constraints, possibly occasionally binding, can be explicitly included in the model to generate nonlinear effects of the shock. Moreover, a banking sector can be introduced to explicitly model a bank balance sheet channel, whose effect we implicitly capture through the simulated demand and supply shocks.[31] A labor market with search and matching frictions, featuring equilibrium unemployment, can be introduced in the model. Other fiscal measures could be considered, such as a labor tax reduction or transfers to liquidity-constrained firms. We leave these issues for future research.

[31] Lower asset prices could amplify the propagation of the shocks via the banks' balance sheet, in particular if the policy rate is at the ELB, while, to the opposite, non-standard measures like central bank asset purchases could favor banks' balance sheet by sustaining asset prices. See Bartocci et al. (2019) for a model evaluating the impact of central bank asset purchases on the banking sector.

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Table 1: Main variables

	Home	REA
Macroeconomic variables		
Private consumption	59	59
Public consumption	21	21
Investment	20	20
Imports	20	20
Imports of consumption goods	16	16
Imports of investment goods	4	4
Share of EA GDP	50	50
Inflation rate (%, annualized)	2	2
Financial variables		
Nominal short-term rate (%, annualized)	2	2
Nominal long-term rate (%, annualized)	2.3	2.3
Long-term public debt	100	100
Share held by Ricardian households	50	50
Share held by restricted households	50	50
Short-term public debt	6	6
Net foreign asset position	0	0

Note: REA = rest of the euro area. Public debt as % of annualized output; other variables are % of output.

Table 2: Preferences and technology

Parameter	Home	REA
Ricardian households discount factor $\beta_{ric}, \beta^*_{ric}$	0.9998	0.9998
Restricted' discount factor $\beta_{res}, \beta^*_{res}$	0.999	0.999
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0
Habit *bb*	0.7	0.7
Inverse of Frisch elasticity of labor supply τ	2.0	2.0
Share of households in population		
Ricardian households λ_{ric}	0.55	0.55
Restricted households λ_{res}	0.2	0.2
HTM households $1 - \lambda_{ric} - \lambda_{res}$	0.25	0.25
Share of households in capital producers		
Ricardian households $share_{k_{ric}}$	0.4	0.4
Restricted households $1 - share_{k_{ric}}$	0.6	0.6
Intermediate goods		
Depreciation rate of capital δ	0.025	0.025
Elasticity subst. btw. factors of production	1.0	1.0
Bias towards capital	0.35	0.35
Final consumption goods		
Elasticity subst. btw. dom. and imported goods	1.50	1.50
Bias towards domestic tradable goods	0.80	0.80
Final investment goods		
Elasticity subst. btw. dom. and imported goods	1.50	1.50
Bias towards domestic tradable goods	0.80	0.80

Note: REA = rest of the euro area. "*" refers to REA.

Table 3: Gross markups

Markups (elasticities of substitution)		
	Intermediate goods	Wages
Home	1.2 ($\theta_T = 6.0$)	1.33 ($\psi = 4.3$)
REA	1.2 ($\theta_T^* = 6.0$)	1.33 ($\psi^* = 4.3$)

Note: REA = rest of the euro area. "*" refers to REA.

Table 4: Adjustment costs

Parameter	Home	REA
Ricardian households		
Long-term sovereign bond $\phi^I_{ric,long}$, $\phi^{I,*}_{ric,long}$	0.001	0.001
Long-term sovereign bond $\phi^{II}_{ric,long}$, $\phi^{II,*}_{ric,long}$	0.001	0.001
International bond ϕ_{B1}	0.05	–
International bond ϕ_{B2}	0.05	–
Resctricted households		
Long-term sovereign bond $\phi_{res,long}$, $\phi^*_{res\_long}$	0.001	0.001
Firms		
Physical capital ϕ_I, ϕ^*_I	6.0	6.0
Wage and Prices		
Nominal wages κ_W, κ^*_W	400	400
Home intermediate tradable goods κ_H, κ^*_H	380	380
REA intermediate tradable goods κ_{REA}, κ^*_{REA}	380	380
Home price indexation to past inflation α_H, α^*_H	0.7	0.7
REA price index. to past inflation α_{REA}, α^*_{REA}	0.7	0.7
Wage indexation to past inflation α_W, α^*_W	0.7	0.7

Note: REA = rest of the euro area. "*" refers to REA.

Table 5: Monetary and fiscal policy rules

Parameter	Home	REA	EA
Fiscal policy rule and tax rates			
$\phi_G, \phi_G^*, \phi_G^{EA}$	0.6	0.6	0.6
τ_c, τ_c^*	0.2	0.2	–
τ_w, τ_w^*	0.4	0.4	–
τ_k, τ_k^*	0.3	0.3	–
Monetary policy rule			
Lagged interest rate ρ_r	–	–	0.87
Inflation ρ_π	–	–	1.70
output growth ρ_y	–	–	0.10

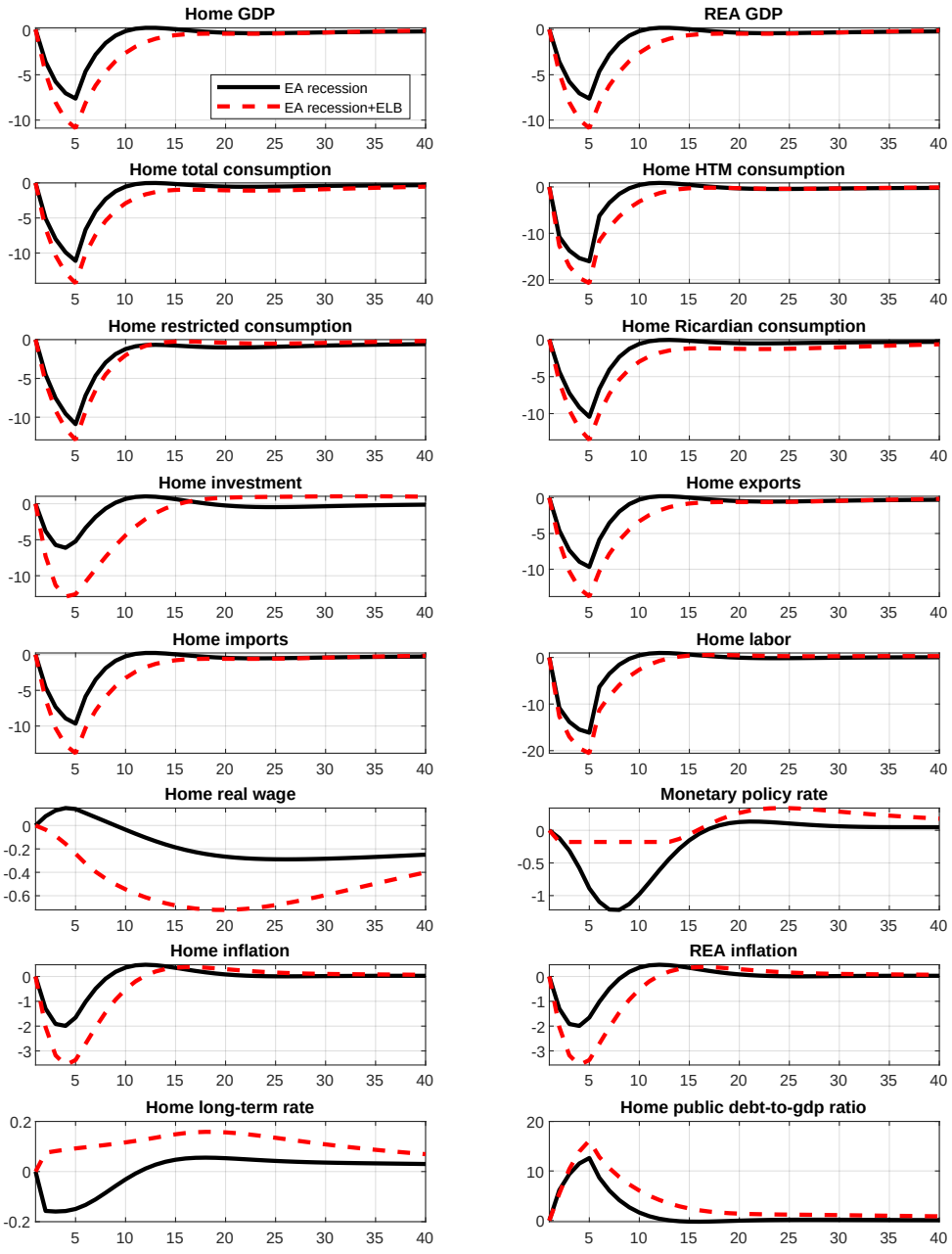
Note: EA = euro area; REA = rest of the EA. "*" refers to REA.

Table 6: Implicit fiscal multipliers: real GDP response

Fiscal stimulus	Home multiplier	REA multiplier
Only Home	0.9	0.2
Home+REA	1.1	1.1
Home+REA+non-standard mon. pol.	1.4	1.4
Home+REA+increase in Home sovereign spread	0.8	1.0
Home+REA (supranational fiscal authority)	1.1	1.1

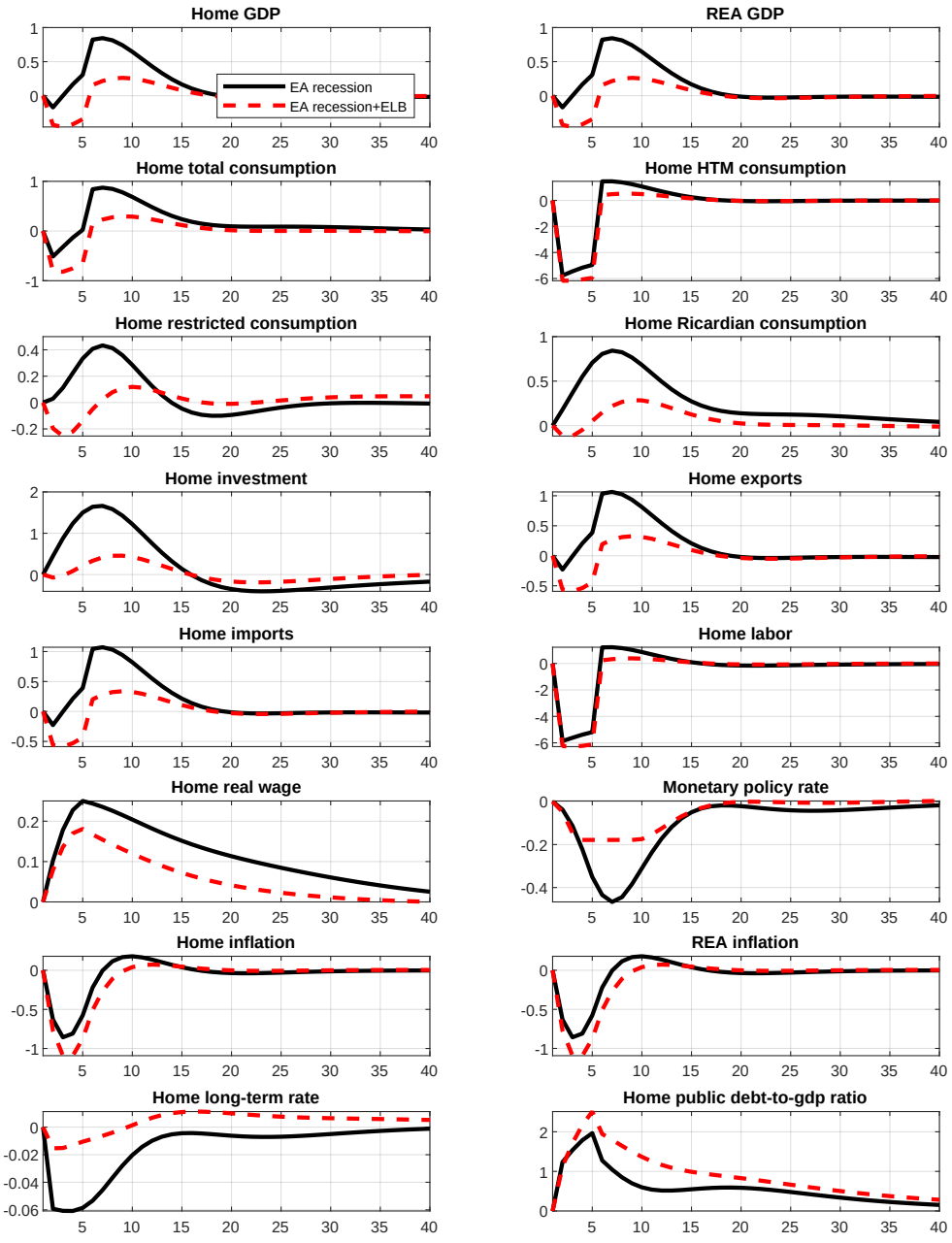
Note: REA = rest of the euro area.
The implicit multiplier is computed as the difference, in the fourth quarter, between GDP with fiscal stimulus and GDP without fiscal stimulus, divided by the size of fiscal stimulus. In the fourth quarter the fiscal stimulus ends and, in the no-stimulus scenario, GDP achieves its trough.

Figure 1: Covid-19 shock and ELB



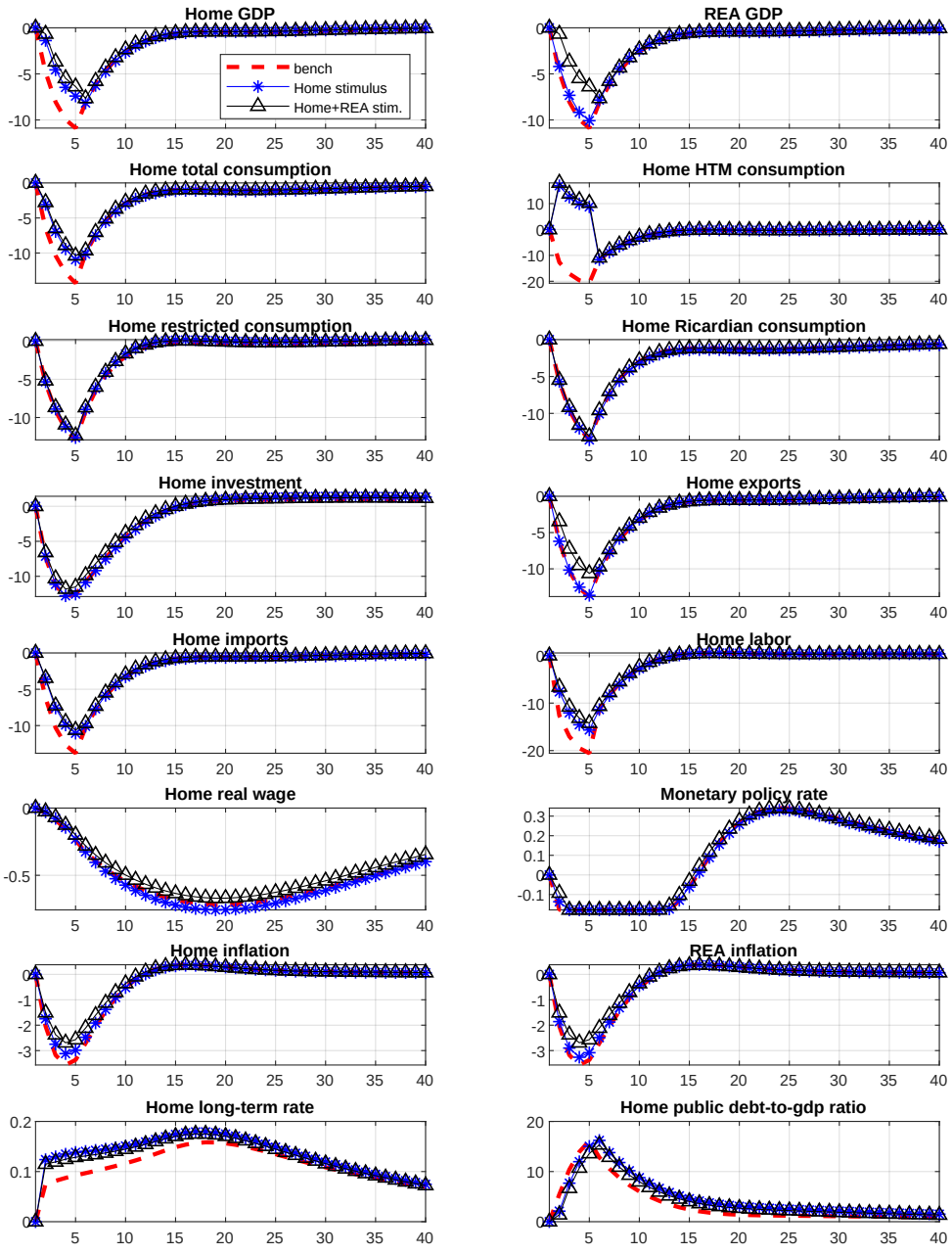
Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation and interest rate: annualized pp deviations; public debt: ratio of annualized GDP, pp deviations.

Figure 2: Covid-19 shock and ELB: the role of the supply shock



Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation and interest rate: annualized pp deviations; public debt: ratio of annualized GDP, pp deviations.

Figure 3: Covid-19 shock and public spending



Notes: quarters on the horizontal axis; on the vertical axis, % deviations from the baseline; inflation and interest rate: annualized pp deviations; public debt: ratio of annualized GDP, pp deviations.

Figure 4: Covid-19 shock, public spending, and sovereign bond purchases by central bank

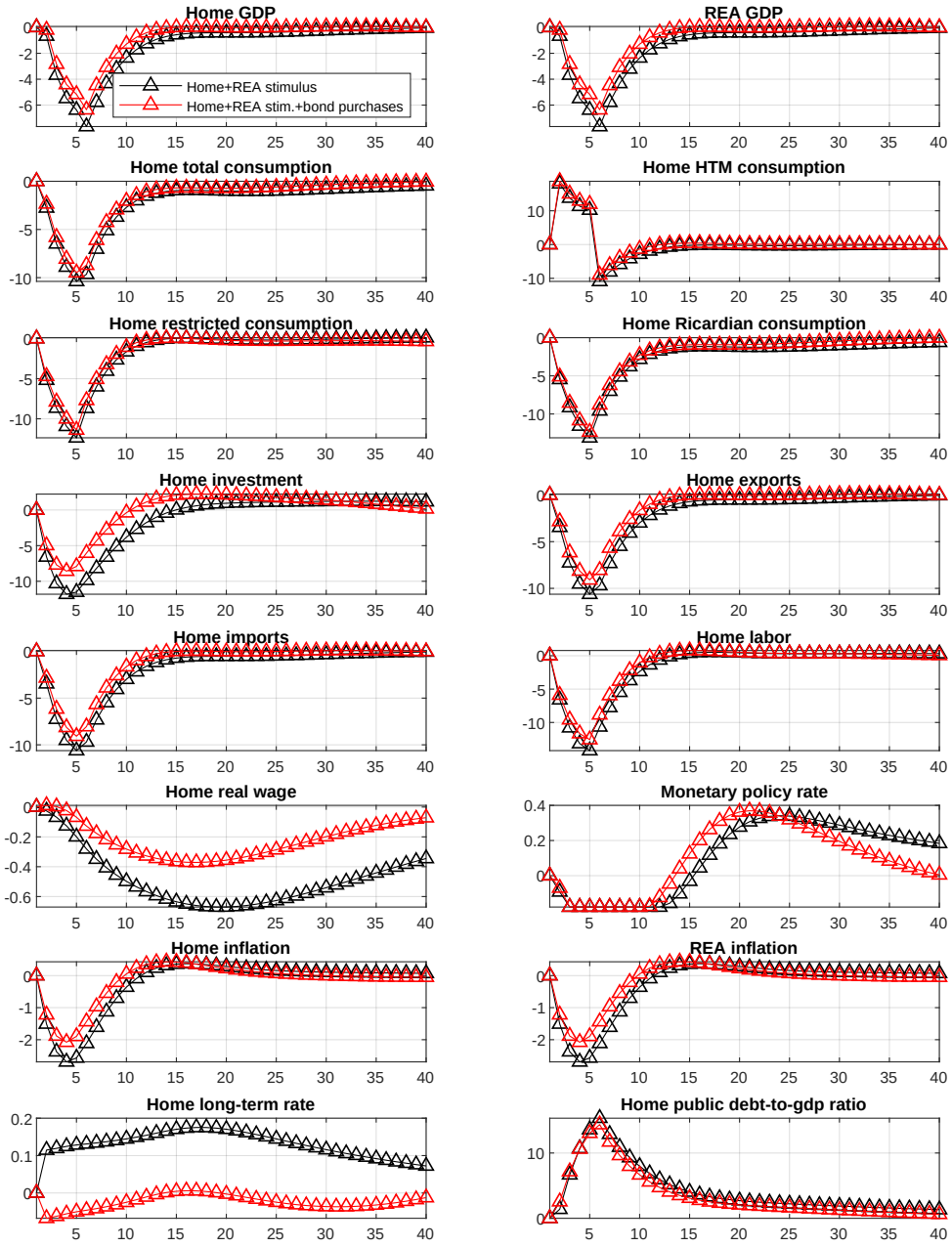


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Figure 5: Covid-19 shock, higher public spending, and spread

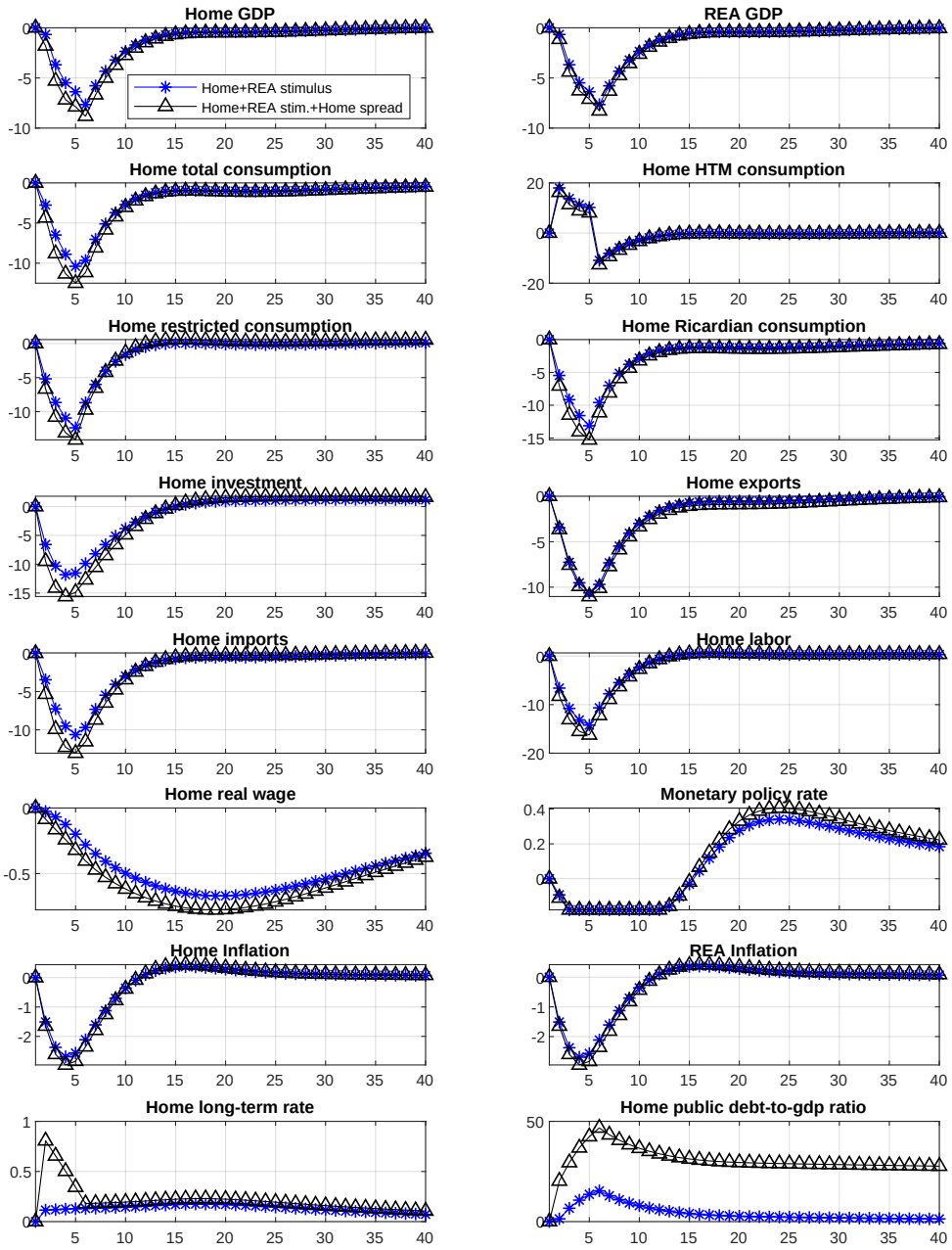

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Figure 6: Covid-19 shock and supranational fiscal authority's public spending

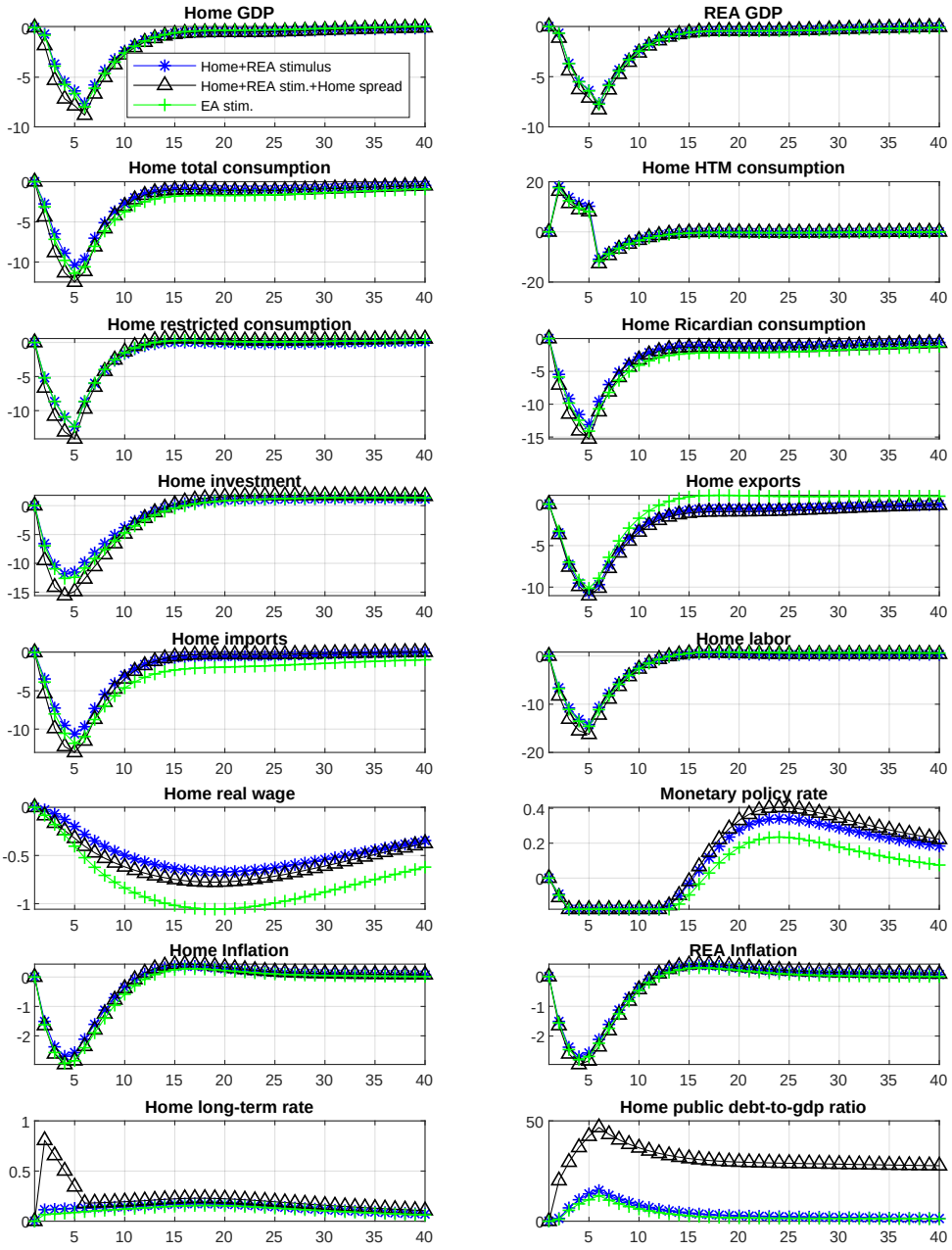

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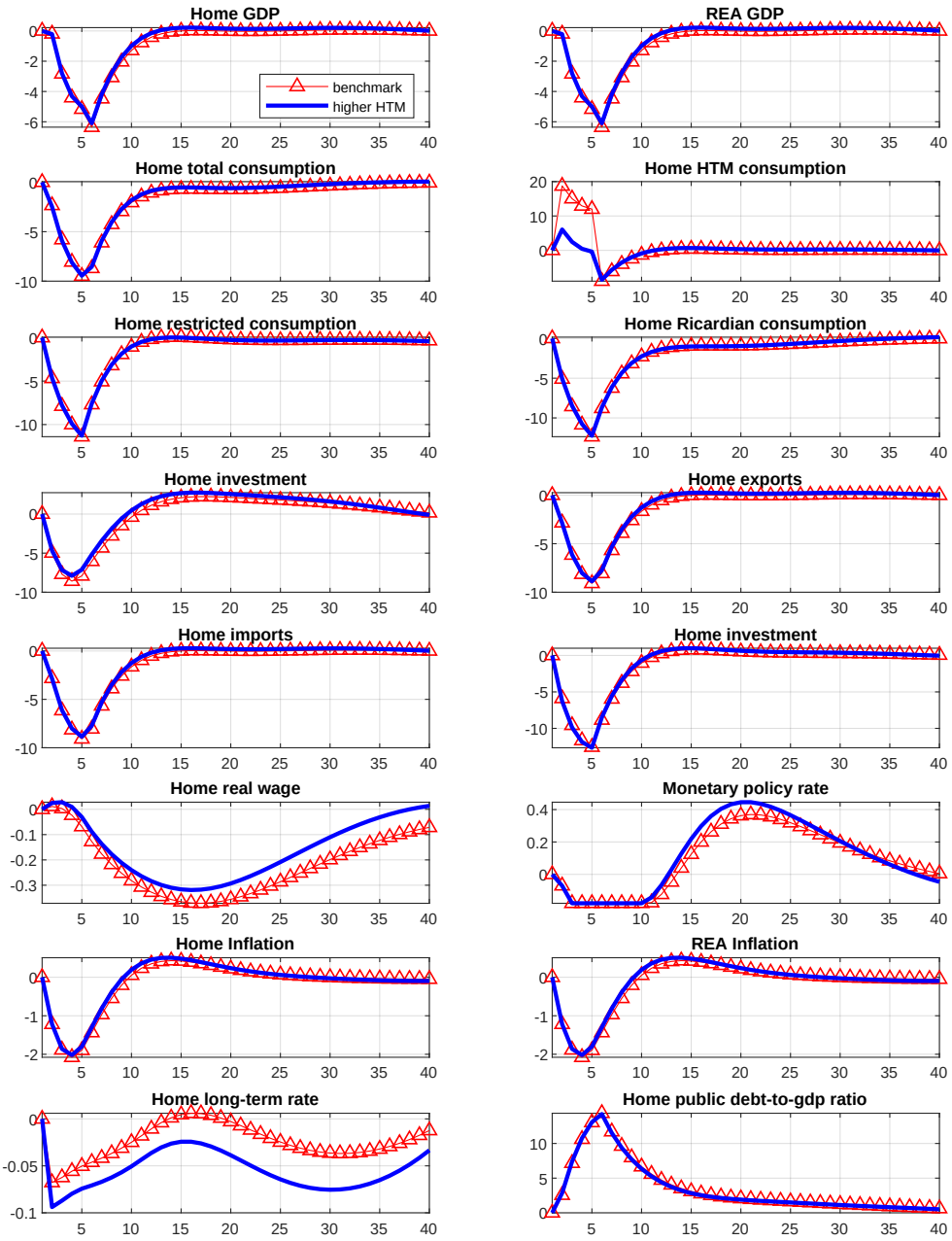
Figure 7: Sensitivity: higher HTM households' share



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